INVESTIGATION ON NORTH AMERICAN TRAFFIC CALMING DEVICE SELECTION PRACTICES

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Traffic calming provides a process for identifying and addressing existing problems related to speeding, excessive traffic volume, and pedestrian safety concerns on residential streets. Although several traffic calming devices have been installed in Asian countries for example in Japan and Korea; they have no distinct and methodical process for the device selection. The objective of this research is to illustrate a comprehensive review of North American traffic calming device selection process practices. The aim is to establish traffic calming device selection process guiding principles to be introduced in Japan. This research reveals that speeding is the most significant issue for installing a traffic calming device. The result explores that community support is the most important factor for the selection of a traffic calming device. The result shows that speed humps and speed tables or raised crosswalks are the most widely practiced devices.

Key Words: Traffic calming, Device selection process, Speeding, guiding principle, Community support

1. INTRODUCTION

Traffic calming is a way to manage traffic so that its negative impacts on residents and pedestrians are minimized. Reducing traffic speeds and volumes can reduce the severity[1] of vehicle crashes, particularly those involving pedestrians and bicyclists. Basically traffic calming is concerned with reducing the adverse impact of motor vehicles on residential streets. It can reduce vehicle speed and volumes and allows more space for pedestrians and cyclists. These schemes generally incorporate a wide range of measures for example: speed humps, speed tables, raised crosswalks, chicanes, chokers, roundabouts, circles and pavement markings. Traffic calming can be an important part of Transportation Demand Management (TDM) programs by creating streets that are more suitable for walking, bicycling and public transit[2].

Vertical and horizontal deflections are important in reducing speeds and consequently, accidents. However, it is clear that the success of such schemes is not determined only by objective measures of their effect (on speed, flows and accidents) but that subjective assessment is also important[3]. If the introduced measures are not well accepted by the public, these soon become discredited, leading in some cases to the removal of measures, which is not cost effective.

The public's perceptions can also be changed by the introduction of traffic calming; particularly the feeling that the environment is safer after the introduction of a scheme. In the Danish town of Vinderup surveys found a marked change in the perceived safety of the road. Eighty percent of adult pedestrians felt safe afterwards compared with 51% beforehand; similarly 75% of cyclists and 76% of car drivers felt safe with the scheme compared with 17% and 56% respectively prior to the traffic calming being carried out[4].

Experience has shown that reductions in vehicle speed may also lead to reductions in noise, although excessive use of low gears and frequent acceleration and deceleration may increase noise levels. Where speeds have been reduced from 50 to 30kph, typical reductions in noise levels of between 4 to 5 dBA have been measured[4].

Several cities have implemented traffic calming measures for example- speed humps, speed tables, traffic circles, curb extensions, diverters, medians and a range of other measures to reduce the vehicle speed and volume. Although few cities have been successful with traffic calming efforts, some have created more problems than they have solved. This happens in many Asian countries like Japan. Several traffic calming devices have been installed in Japan. But these are not very effective since no standard design guideline was followed during installation process. Typically such a situation occurs when traffic calming measures are applied without an overall plan.

Thus the objective of this research was to perform a comprehensive review of the traffic calming device selection process practices in the North America and other international communities. The scope is to establish a reasonable outline and scope for the process to introduce in Asian countries.

2. LITERATURE REVIEW

Speeding traffic hinders our ability to enjoy neighborhoods– creating noise and making it hard to walk, cycle or drive safely. The goal of traffic calming is to make our streets safer and more comfortable for all users and residents. Traffic calming involves implementing strategic measures to reduce vehicle speed, excessive traffic volume, cut-through traffic on residential streets, and other safety-related neighborhood traffic concerns. Through the use of a variety of measures, physical or otherwise, traffic calming helps reduce the undesirable effects of the motor vehicle in residential neighborhoods. Traffic calming exercises were reviewed from manuals and practices of different North American, European and Australian jurisdictions to gain a clear understanding of the process.

There may be several issues for traffic calming in the neighborhood streets such as speeding, high volume of traffic, accidents, pedestrian and cyclists' safety concerns. In order to effectively address a traffic calming issue, it is important that the issue be accurately described. Otherwise, a traffic calming solution might be developed which does not do enough to fully address the issue, or which does too much and is more restrictive than is needed to address the issue[5].

Japan has introduced traffic calming named "Community Zone" or Zone 30 in 1996. There are 160 Community Zones in Japan. Among these 62 projects were completed in 2001 and many of them are ongoing projects. In 2003 Japan started a new version of Community Zone named "Kurashino Michi Zone"[6]. In 2008, 44 projects of Kurashino Michi Zone were completed and 11 projects are still ongoing[7].

The neighborhood support determines the level of residents' support for the proposed traffic calming. The method for determining neighborhood support may vary for different jurisdictions. A minimum response rate and approval rate must be met from individuals on the treated street before the plan is forwarded to the Board of Supervisors. For implementation of speed control devices, in Sacramento, California a minimum of 50 percent of all ballots must be returned with a simple majority in favor of the plan (50% + 1). For example, if 100 ballots are mailed out, at least 50 must be returned with 26 in favor of the proposed plan. If the plan includes volume control measures, a minimum of 50 percent of ballots must be returned with 67 percent of residents in favor[8].

A study performed by the City of Portland evaluating over 500 speed humps and was reported in the City of Portland Speed Bump Peer Review[9] (Kittleson and Associates, 1998). The results show that:

(i) On average, speed humps reduced 85th percentile travel speeds by about 7 mph after speed humps were installed. Average speed over the speed humps was about 25 mph.
(ii) After installing longer speed humps (22-foot), traffic volumes decreased by an average of 21%. The results of the public opinion survey showed that 64% of the respondents who lived on streets treated with speed humps perceived a reduction in traffic volumes.
(iii) The crash rate (annual crashes per average daily traffic, ADT) decreased on treated streets an average of 5% after speed humps were installed.

A change in the public's attitudes to traffic calming was found in the German town of Buxtehude. Surveys before and after the implementation of a scheme found 46% of car drivers and 49% of residents opposed to the project prior to its construction, and yet three years later 67% of car drivers and 76% of residents were in favor[10].

Vertical shifts in the carriageway have a greater impact on vehicle speeds than any other measure. Other measures such as lateral shifts, carriageway constrictions, roundabouts, small corner radii and changes in priority have an impact on vehicle speeds, but the 85th percentile speed generally remains above 30kph, although average speeds may be below the 30kph threshold[10]. Table 1 gives an indication of the relative speed reductions achievable from a number of traffic calming measures. The "before" situation refers to a road with a 48kph speed limit.

A series of speed humps/tables are often more effective in reducing speeds than single installations since it prevents a vehicle from speeding up after negotiating a single device[11]. The effectiveness of vertical shifts in the roadway, such as speed humps and speed tables is dependent upon spacing. Reductions in the incidence and severity of crashes of 50 percent or more are frequently reported, as summarized[12] in Table 2. However, most traffic calming projects result in reductions in traffic volume and many of the safety studies do not take this diversion into account. It is possible the crashes may be migrating to other roads.

Table 1 Expected speed reduction effect of various traffic calming measures

Traffic calming measures	Upper limit of max speed (kph)		Upper limit of 85th percentile speed (kph)		Range of average speed (kph)	
	Before	After	Before	After	Before	After
Vertical shifts in the carriageway	100	40	75	30	45-65	18-25
Lateral shifts in the carriageway	100	65	75	45	45-65	22-35
Road narrowing to a single lane	100	65	75	45	45-65	22-35
Roundabout	100	65	75	45	45-65	22-35
Road narrowing to a reduced width	100	95	75	70	45-65	40-55
Central islands	100	95	75	70	45-65	40-55

Table 2 Summary of the effects of traffic calming measures[11]

Reference	Country	Measure	Results
Zidel et al. (1986)	UK	Rumble strips	Mean speeds reduced by 40%
Bowers(1986)	Germany	Speed tables, narrowing, chicanes, gateways	No change in crash rate Injuries reduced by 50%
Chua and Fisher (1991)	Australia	Various methods	Crashes reduced by 50% Through traffic reduced by 35% Vehicle speeds reduced by 25%
Herrstedt (1992)	Netherlands	Various methods (staggering, gateways)	Vehicle speeds reduced 6 mi/h (10 km/h)
Kjemtrop and Herrstedt (1992)	Netherlands and France	Various methods (humps, staggering)	Crashes reduced by 30 to 60%
Engel and Thomsen (1992)	Denmark	Various methods (humps, staggering)	Speeds reduced by 7 mi/h (11 km/h) Injury rate reduced 72% in calmed areas Injury rate increased 96% on adjoining streets
Vis et al. (1992)	Netherlands	Humps, staggering, islands	Speeds reduced by 20%; Volumes reduced 5-30% Crashes reduced by 5%, injury crashes by 25%
Webster (1993)	UK	Speed humps	85th percentile speeds reduced 10 mi/h (16 km/h) Crashes reduced 71% on treated streets Crashes reduced 8% on surrounding roads
Dahlerbrach (1993)	USA	Speed humps	Speeds reduced by 14% (5 mi/h) Traffic volume reduced by 7%
Halbert et al. (1993)	USA	Speed humps, Traffic circles	85th percentile speeds reduced by 30% 85th percentile speeds reduced by 22%
Bulpitt (1995)	UK	Humps and chicanes	Speeds reduced by 10 m/h (16 km/h) Crashes reduced up to 80% and traffic by 30 to 50%
Wheeler and Taylor (1995)	UK	Gateway signing, marking, narrowing	Speeds reduced 0-12 mi (0-19 km/h) Injury accidents decreased 14%
Webster and Mackie (1996)	UK	Mostly humps and speed tables	Speeds reduced by 9 mi/h (14 km/h) Crashes reduced by 61 percent
Griffin and Reinhard (1996)	Japan UK	Chevron markings Transverse markings	Crashes reduced 25 to 50% Crashes reduced 5 to 50%
Ewing et al. (1998)	US	Speed humps Mini-circles	Crashes reduced 13%; speeds by 22% Crashes reduced 18%; speeds by 14%

A study of 119 residential traffic circles installed in the city of Seattle between 1991 and 1994 found that reported accidents in those areas declined from 187 before installation to 11 after installation, and injuries declined from 153 to one[13].

A survey[14] of 35 British calming schemes, with the

majority including vertical shifts in the carriageway, found that the average reduction in the 85th percentile speed was 16kph (10mph).

3. DATA COLLECTION

This research started with a comparative study of the traffic calming decision making process, through a rigorous literature review of traffic calming programs and practices. Japan is one of the Asian countries which do not have well defined and methodical procedure to select the traffic calming devices. A questionnaire survey was therefore undertaken to gather information regarding the traffic calming device selection process of North American cities and some other communities of Australia, and Europe. The questionnaire survey was conducted from 22nd October 2008. The respondents were Traffic and Transportation Decision Making Organizations/Specialists from North America, Australia, and Europe. Topic areas covered by the questionnaire survey were about the traffic calming device selection process, residents support for the device selection process, and after effects of the devices. About 205 questionnaires were sent through e-mail, fax and by postal mail to

- the United States Department of Transportation,
- Canadian Roads and Transport Authority,
- Department for Transport in Europe including some County Councils,
- Australian Roads and Traffic Authority, and
- New Zealand Land Transport Authority.

Listed below are the 36 transportation agencies that replied to the survey:

Respondents from North America:

1. City of Albuquerque (NM)
2. City of La Mesa (CA)
3. West Palm Beach (FL)
4. Anchorage (AK)
5. Salt Lake City (UT)
6. Gwinnett County (GA)
7. Hillsborough County (FL)
8. Naples, Collier County (FL)
9. Austin (TX)
10. Greenville County (TX)
11. Washington County (OR)
12. Portland (OR)
13. Knox County (TN)
14. Lakeland (FL)
15. Dublin (OH)
16. City of Sandy (OR)
17. North Richland Hills (TX)
18. Sarasota (FL)
19. Henrico County (VA)
20. District of Columbia (WA)
21. Beaverton (OR)
22. City of Bellevue (WA)
23. Northport (AL)
24. Prince George's County (MD)
25. Delray Beach (FL)
26. Peoria (AZ)
27. Baltimore County (MD)
28. Albany (OR)
29. West Jordan (UT)
30. Orlando (FL)
31. Clackamas (OR)
32. Town of Cary (NC)
33. Calgary (AB)

Respondent from Europe:

34. Cheshire County Council, (Cheshire)
35. Merthyr Tydfil (Wales)

Respondent from Australia:

36. Gordon, NSW (Ku-ring-gai council)

The response rate was 18%. Overall 32 respondents replied from different United States Departments of Transportation (DOT), 1 from Canadian Roads and Transport Authority, 2 from the Department for Transport in Europe and County Councils, and 1 from the Australian Roads and Traffic Authority.

4. SURVEY RESULTS

Most cities require documentation of a minimum threshold level of public support prior to construction of a traffic calming device. The transportation agencies had been requested for the minimum neighborhood support they require in order to install a traffic calming device. The level of support is determined by an initial petition form that needs to be signed by a least percent of the residents indicating a traffic concern in the neighborhood, but does not recommend any specific solution. Figure 1 shows the least percent of residents' support that must be met for traffic calming device installation.

The average level of desired neighborhood support for traffic calming is 67%. The minimum level of neighborhood support varies. The City of Sandy, Oregon requires 50% public support; Dublin, Ohio requires 95% support from those residents who either live on or are directly adjacent to the street in question. Figure 2 shows that the minimum threshold level of public support prior to construction varies from 61% to 70% for 41% of the

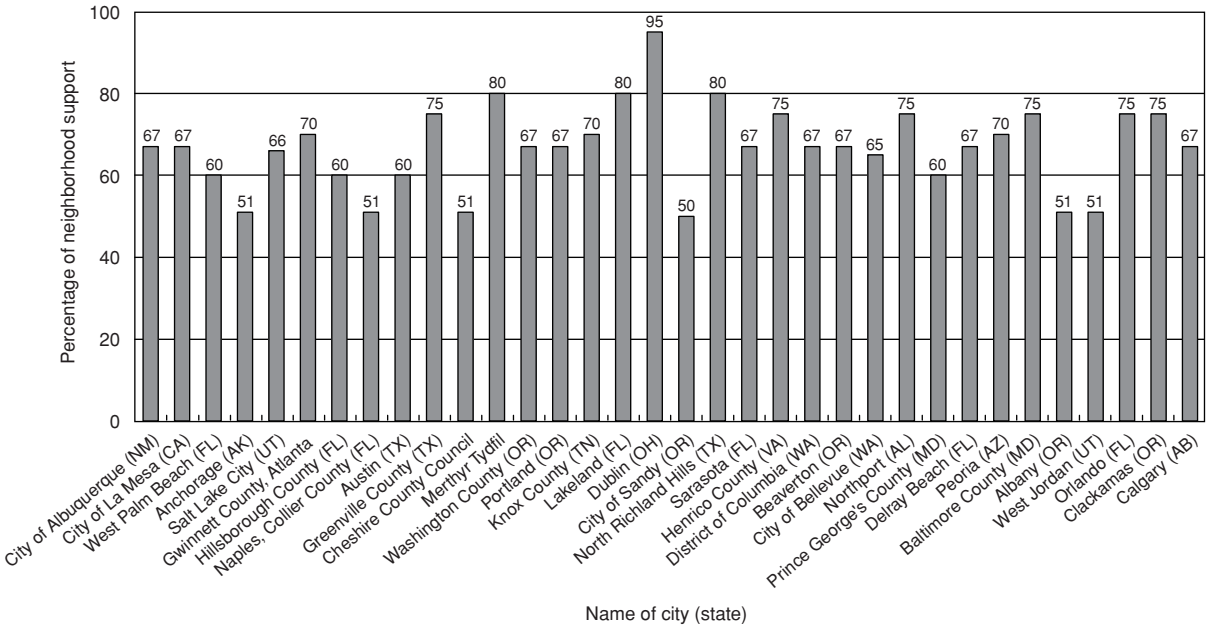

Fig. 1 Minimum level of neighborhood support to install traffic calming device

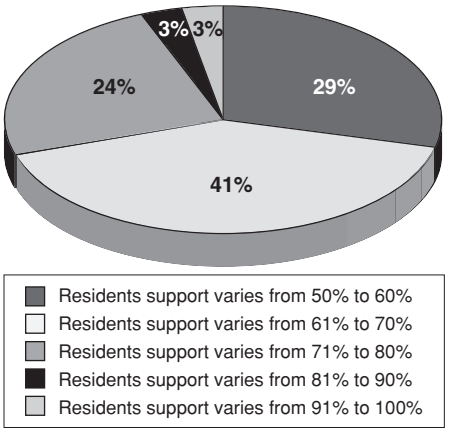

Fig. 2 Variation of neighborhood support to install traffic calming device

respondent agencies. There are a few respondents who do not specify a necessary level of public support.

The survey reveals the residents support that the transportation agencies received before and after the traffic calming device installation. Table 3 shows residents' support for traffic calming before and after devise installation.

Figure 3 shows that residents support for traffic calming before device installation varies from 10% to 100%. Whereas residents support for traffic calming after device installation varies from 0% to 95%. The average level of neighborhood approval before traffic calming device installation is 74% and after device installation is 67%. The result shows that:

(i) residents' support for traffic calming for 41% of the cities remains equal before and after the installation of traffic calming device installation;
(ii) residents' support for traffic calming for 33% of the cities is higher before traffic calming device installation than after;
(iii) residents' support for traffic calming for 25% of the cities decreases after traffic calming than the support before installation.

For the City of Sandy, Oregon this level of approval was only from the individuals who either live on the street or are directly adjacent to it. Other residents, who use the street, but don't live on or near it would have a much lower support rate, only in the 30% range or so.

The survey explores the level of neighborhood opposition and/or controversy for which the transportation agencies cannot install a traffic calming device. The average level of neighborhood opposition is 67%. Figure 4 shows that neighborhood opposition varies from 1% to 80%. The City of Bellevue, Washington cannot install if 1% of residents say they do not want the device; Lakeland, Florida cannot install a device for 79% opposition from the residents.

Cities consider residents support at all stages of the traffic calming process. For the District of Columbia Department of Department of Transportation, requests for a

Table 3 Residents' support for traffic calming before and after devise installation

Country	Province (State)	Residents' support for traffic calming before devise installation, %	Residents' support for traffic calming after devise installation, %
USA	City of La Mesa (CA)	80	80
USA	West Palm Beach (FL)	61	
USA	Anchorage (AK)	90	10
USA	Salt Lake City (UT)	10 residents	
USA	Gwinnett County (GA)	80	90
USA	Hillsborough County (FL)	79	
USA	Collier County (FL)	10	51
USA	Austin (TX)	30	70
USA	Greenville County (TX)	75	75
USA	Washington County (OR)	67	67
USA	Portland (OR)	75	75
USA	Knox County (TN)	70	90
USA	Lakeland (FL)	80	95
USA	Dublin (OH)	95	95
USA	City of Sandy (OR)	80	75
USA	North Richland Hills (TX)	80	80
USA	Sarasota (FL)	100	0
USA	Henrico County (VA)	80	80
USA	District of Columbia (WA)	67	34
USA	Beaverton (OR)	100	
USA	City of Bellevue (WA)	65	90
USA	Northport (AL)	90	0
USA	Prince George's County (MD)	100	
USA	Delray Beach (FL)	50-75	75
USA	Peoria (AZ)	100	100
USA	Baltimore County (MD)	75	not sure
USA	Albany (OR)	70	75
USA	West Jordan (UT)	70	70
USA	Orlando (FL)	75	75
USA	Clackamas (OR)	80	80
USA	Town of Cary (NC)	100	
Australia	Gordon (NSW)	50	50
Canada	Calgary (AB)	70-80	
UK	Cheshire County Council	51	
UK	Merthyr Tydfil	80	50

traffic calming study must be initiated through advisory Neighborhood Commissions, ANC's (and with their concurrence) with the support of at least 35% of the households on the block(s) where the device is requested. The implementation of any traffic calming measure should have the support of at least 65% of the residents within the study area with the concurrence of the area's ANC. With a broad support of the neighborhood (at least 75% of households), the District of Columbia Department of Transportation would consider the removal or modification of a traffic calming measure if it fails to meet the intended objective or if it leads to the development of unsafe traffic operations. The removal or modification should also be based on analyses conducted after installation.

Different cities may have different types of issues for traffic calming. The questionnaire survey explores different issues for traffic calming and their degree of importance using a Likert scale. According to the degree of importance the respondents' were requested to use '1' for most significant issue, '2' for the issue of next greatest significance and so onward. Figure 5 shows that speeding is the "most significant" factor for traffic calming. High volume of traffic and pedestrian safety concerns are "significant issues" for traffic calming. Lack of pedestrian crossings and lack of sidewalks are "somewhat significant" factors and crashes are "insignificant" for the issues

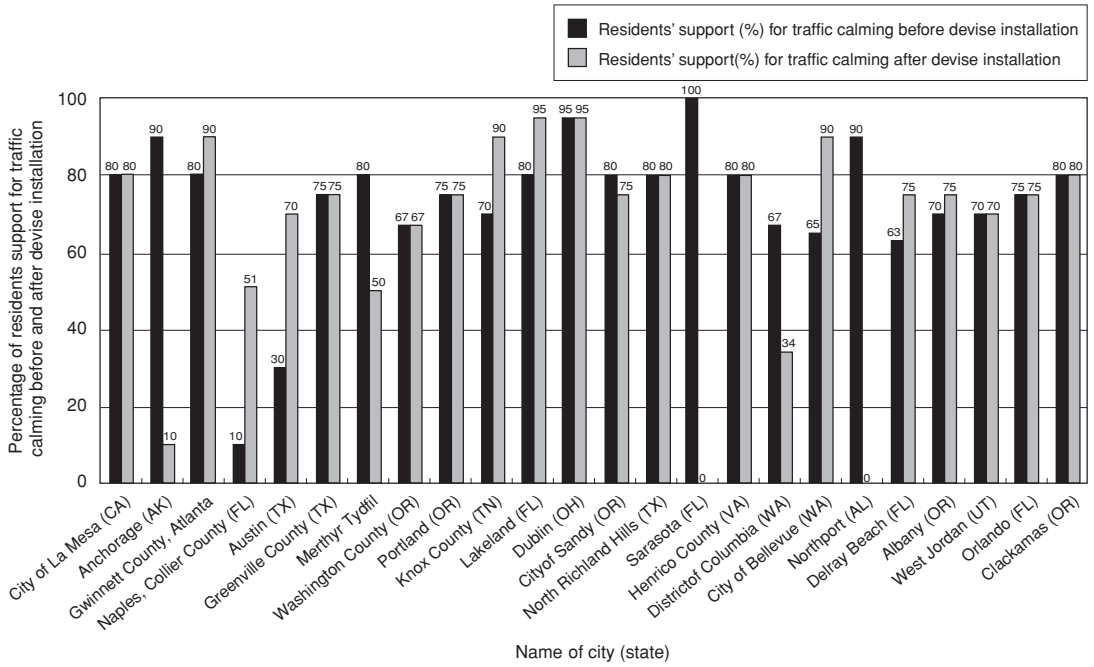

Fig. 3 Percentage of residents support for traffic calming before and after devise installation

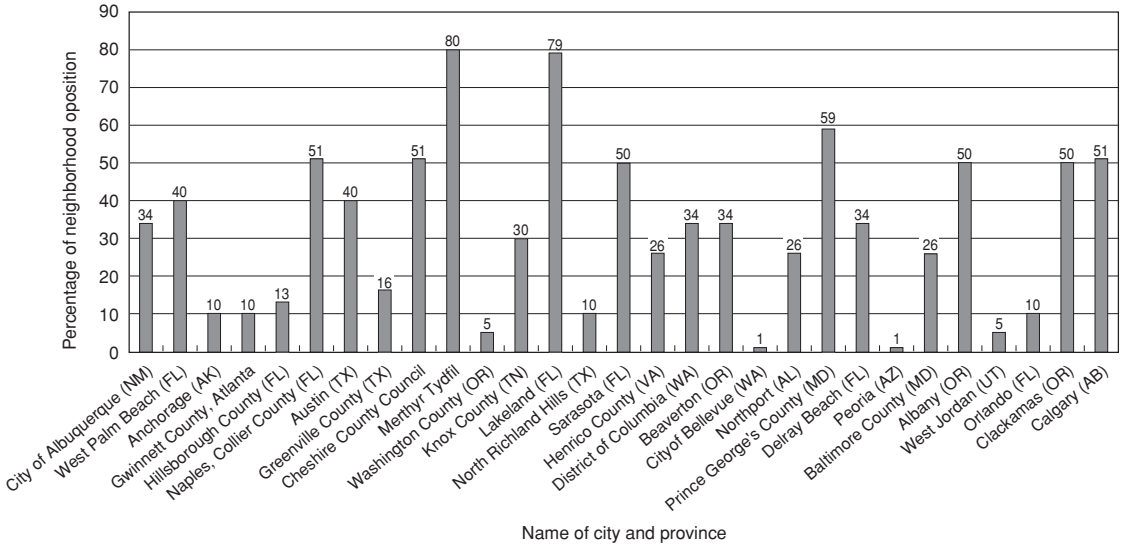

Fig. 4 Level of neighborhood opposition for which traffic calming device cannot be installed

for traffic calming.

Table 4 shows that speeding is most the important factor for traffic calming having the lowest mean value (ranked by the respondents using a Likert scale). The factors of next greatest importance are pedestrians' safety concerns, high volume of traffic, crashes, lack of sidewalks and lack of pedestrian crossing.

The survey reveals the list of considerations during the selection of a traffic calming device using a Likert scale. (According to the degree of importance the respondents were requested to use '1' for very important issue', '2' for the issue of next greatest importance and so-forth). Figure 6 shows that community support is the most important factor for traffic calming device selection. Traffic volume, traffic speed and cost effectiveness are the next important factors for consideration during the selection of a traffic calming device.

There are several types of traffic calming devices

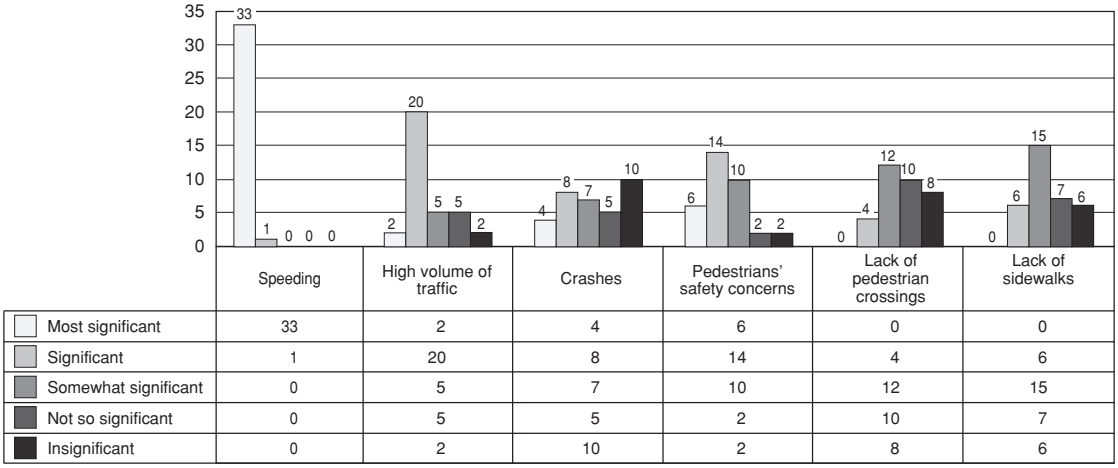

Fig. 5 Factors that best describe the issues for traffic calming and their significance

Table 4 Factors describing the issues of traffic calming

Factors	Speeding	Pedestrians' safety concerns	High volume of traffic	Crashes	Lack of sidewalks	Lack of pedestrian crossing
Mean	1.03	2.41	2.56	3.26	3.38	3.65

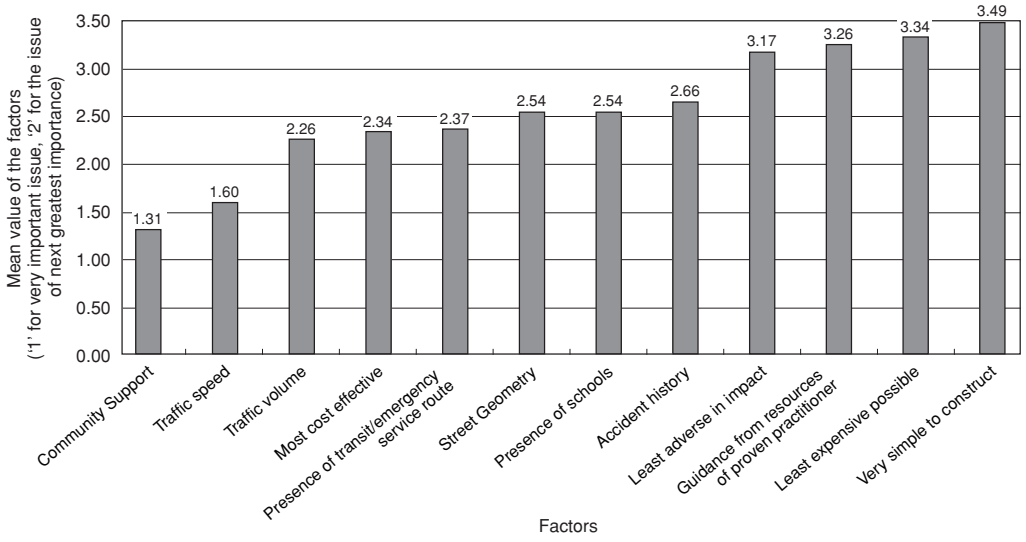

Fig. 6 Factors of consideration during traffic calming device selection

available for cities to introduce. The survey reveals the common practices of device selection as performed by the transportation agencies, which depends on the nature of the issues. The cities were requested to select currently used devices from the chart provided below:

a) Speed hump
b) Speed tables
c) Speed cushions
d) Chokers
e) Chicanes
f) Diagonal diverters
g) Semi diverters
h) Roundabouts
i) Bike lanes
j) Textured/colored pavement
k) Street closures
l) Medians
m) Entry treatment

Table 5 List of devices depending upon the street issues

Type of issue / City (State) name	Speeding	High volume of cut through traffic	Crashes	Pedestrians safety concerns	Pedestrians safety issues due to lack of sidewalks	Narrow street
Albuquerque (NM)	a	a	a		j	
La Mesa (CA)	a, b, d, e, l, n, o, p	a	s	a, b, d, o	b, d, o	a, b, c
West Palm Beach (FL)	A ,h	a, f, k	h			
Anchorage (AK)	a, b ,d, l, n	a, b, d, e, f, j, k, l, n, p		b, d, j, o	j, d, o	
Salt Lake City (UT)	a, r	a, r				
Gwinnett County (GA)	b	b	b	b, p	b, p	
Hillsborough County (FL)	a/b	a/b	s (turn restrictions)	j	s (sidewalk program)	s (one way road)
Collier County (FL)	a, b, e, l. q	a, b, e, q	l, p, k	a, b, i	b, l, i	s
Austin (TX)	c	g, s (entry treatment)	q	l	p	
Greenville County (TX)	b					
Washington (OR)	c, q	g	h	b, j, n	b, j, n	
Portland (OR)	a, b	b, g ,f, l	a, b, l, q	a, b	s (crosswalk is statutory definition)	
Knox County (TN)	a, q	a, q	a, q	a, q	a, q	
Lakeland (FL)	a	a		b	a	
Dublin (OH)	d, e ,l, m, n ,o, q	d, e, l, m ,n ,o, q	d, e, l, m ,n ,o, q	d, e, l, m ,n ,o, q	j, h, p	
Sandy (OR)	a	a		b, n, o, l	b, l	
North Richland Hills (TX)	a, b, c	h, k, q	a, b, c, h, i, l	a, b, c, j, l	j, l	
Sarasota (FL)	b	g		s	s	
Henrico County (VA)	a, c	a, c	a, c	a, c	a, c	
District of Columbia (WA)	a, b	d, g	f, s (no turn restrictions)	b	b, s (install crosswalks)	
Beaverton (OR)	a, c ,n, o, p	a		n, o, p, b	a	
Bellevue (WA)	a, b, c, l, n, o, p, q	a, b, c, d	q	b, n		
Northport (AL)	b	b	b	b	b	
Prince George's County (MD)	a	a, k	s	o	s	
Delray Beach (FL)	e, a, m, s (dividers)	a, e, h, m, s (dividers)				
Peoria (AZ)	a	a				
Baltimore County (MD)	a, b, d, e, h, i, m, n, o, p, q, r	d, h, i, l, m, n, o, p	d, l, m, n, o, r	d, l, m, n, o, r		
Albany (OR)	a, b, e, h, n, o, q	a, e, k, n, o, p, q	a, h, l, n, p	a, h, l, n, o, p, q	l, n, o, p	
West Jordan (UT)	b	b	b	s (warning bars)	s (warning bars & orange flags)	
Orlando (FL)	a	a, h	r	b	a	s (entry treatment)
Clackamas (OR)	a, b, q	a, b, q	h	b, n, o		
Calgary (AB)	a, b, c, h, l, q, r	f, g ,k	l, n	r, n, h	s	
Gordon (NSW)	a, b, c, d, e, h, n, o	a, b ,c, k, m	h, k	a, b, c, d, e, h, n, o, r	a, b, c, j, r	
Cheshire County (Cheshire)	b	b	b	b	b (flat top)	b
Merthyr Tydfil (Wales)	a, b, c, d, e, h, j, o	a, b, c, d, e, k, o	a, b, c, d, j	a, b, c, j	a, b, c	

n) Curb extensions
o) Bulbouts/Pinch point/Neckdown
p) Central island narrowing
q) Circles
r) Raised crosswalks
s) Others

Table 5 shows the list of devices used by the respondents depending on the street safety issues. From the result it can be observed that speed hump is suitable for

various types of street issues such as speeding, high volume of cut through traffic, crashes, pedestrian safety concerns, pedestrian safety issues due to lack of sidewalks and for narrow streets.

The respondents were requested to assign a percentage of the devices employed; for which the sum will be 100%. The last column of Table 6 shows the other devices employed by the agencies which are: driver feedback sign, semi diverters, mini roundabout, and entry treatments, colored pavement treatment, speed dots and pavement bars.

Table 7 shows that speed hump (53%) is the most frequently used device. Speed tables or raised crosswalks (17%), speed cushions (9%), roundabouts (3.47%) and

Table 6 Percentage of the devices used

City (Satate) name	Speed hump	Speedtables or Raised crosswalks	Speed cushions	Chokers	Chicanes	Diverters	Circles	Round-abouts	Medians	Pedes. refuge	Curb exts.	Others
Albuquerque (NM)	90						5	5				
La Mesa (CA)	89	1		5	2				3			
West Palm Beach (FL)	85					5		10				
Anchorage (AK)	70	5		15	10							
Salt Lake City (UT)	76	2										22
Gwinnett County (GA)	98						1	1				
Hillsborough County (FL)	88	10	1			1						
Naples, Collier County (FL)	40	30			10		20					
Austin (TX)			75		3		6		10			6
Greenville County (TX)		100										
Washington County (OR)		5	90				5					
Portland (OR)	50.15	14.4				2.99	4.33	0.06	1.1			27
Knox County (TN)	99						1					
Lakeland (FL)	95	5										
City of Sandy (OR)	85	5		10								
North Richland Hills (TX)	92	1	2				4	1				
Sarasota (FL)		50	5	10	10	5	10	10				
Henrico County (VA)	80		20									
District of Columbia (WA)	80	10		5		5						
Beaverton (OR)	30	35	25	9				1				
City of Bellevue (WA)	34	0	1	37	1	1	3					23
Northport (AL)		100										
Prince George's County (MD)	98							1				1
Delray Beach (FL)	20				20		20		20		20	
Peoria (AZ)	80		15	1	1	1	1	1				
Baltimore County (MD)		60		5	5	5	1	2	2	15	5	
Albany (OR)	65				5			5	5	5	15	
West Jordan (UT)	10	70		5				5	5		5	
Orlando (FL)	80	10						10				
Clackamas (OR)	80	5					5	10				
Calgary (AB)	22	15	5			5	10	5	10	5	23	
Gordon (New Soth Wales)		5			15			35	15	15	5	10
Cheshire County Council (Cheshire)	45	9	40	1	1	1	1	1				1
Merthyr Tydfil (Wales)	25	15	30	10	5			15				

Table 7 Percentage of the devices used

Name of device	1) Speed hump	2) Speedtables/ Raised crosswalks	3) Speed cushions	4) Chokers	5) Chicanes	6) Diverters
Devices used (%)	53	17	9	3	3	1
Name of device	7) Circles	8) Roundabouts	9) Medians	10) Pedestrian refuge	11) Curb extensions	12) Others
Devices used (%)	3	3	2	1	2	3

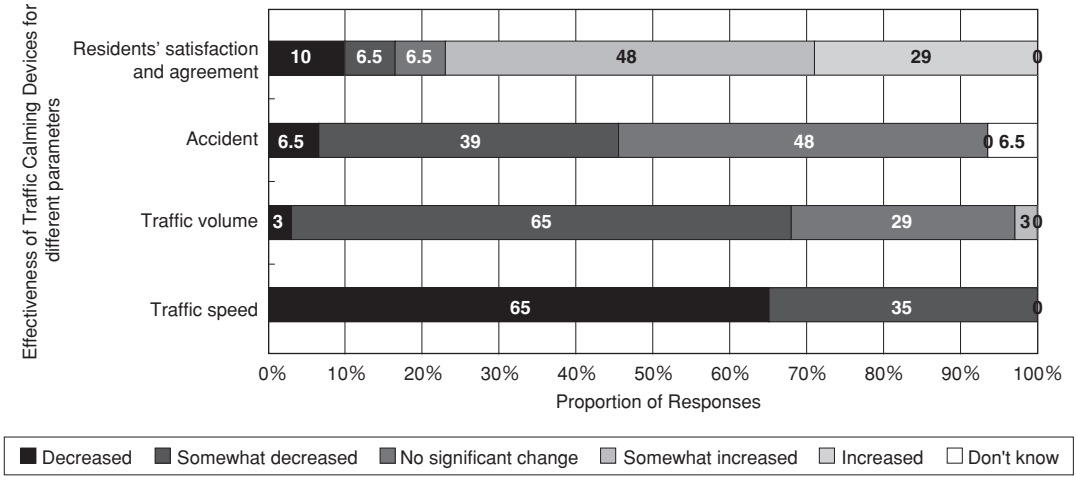

Fig. 7 Effectiveness of traffic calming device/s

chokers (3.32%) are subsequently used devices.

Most cities require a follow-up evaluation of the effectiveness of the traffic calming feature and specify a time range in which the evaluation should be accomplished after installation. Cities often require that the feature be installed for long enough that any evaluation data is not skewed by the newness of the feature. During the evaluation, city staff determines the traffic speed, volume or other measures and compares the data for assessment. This survey reveal the effectiveness of traffic calming devices. Figure 7 shows the effectiveness of traffic calming device/s. The result shows that traffic calming had "decreased" the traffic speed, "somewhat decreased" the traffic volume, "no significant change" in accident, "somewhat increased" the residents' satisfaction and agreement.

The respondents' opinion regarding the existing situations explaining the impact of traffic calming device/s to the nearby dwellings was explored. Figure 8 shows that due to traffic calming traffic noise had "somewhat increased", vibration and environmental pollution had "no significant change", and street aesthetics had "somewhat increased" or there was "no significant change".

The questionnaire survey revealed that traffic calming had "increased" pedestrian safety, "somewhat increased" bicyclists safety, "increased" motorists safety and "somewhat increased" the safety of children playing in the vicinity. Figure 9 shows the safety situations appropriate with the circumstances after the traffic calming devices were implemented.

Figure 10 shows the respondent agencies period for completion of one project (assuming the project will start from a request and end up after evaluation of effectiveness of the device). Most of the responding agencies (40%) require 1-2 year period for completion of one traffic calming project.

Several practices addressed by the jurisdictions in cases where residents of the area desired the removal of one or more existing permanent traffic calming devices. Citizens may request a street segment be reviewed for the possible removal of some or all of the existing devices. A request for the removal of a traffic calming device results in the device removal. To initiate the process, a resident submits a written request to the Transportation Agency to consider the removal of one or more existing permanent traffic calming devices. Responses must be received from a certain percentage of household (depends on each cities regulation) addresses in the project area for the pro-

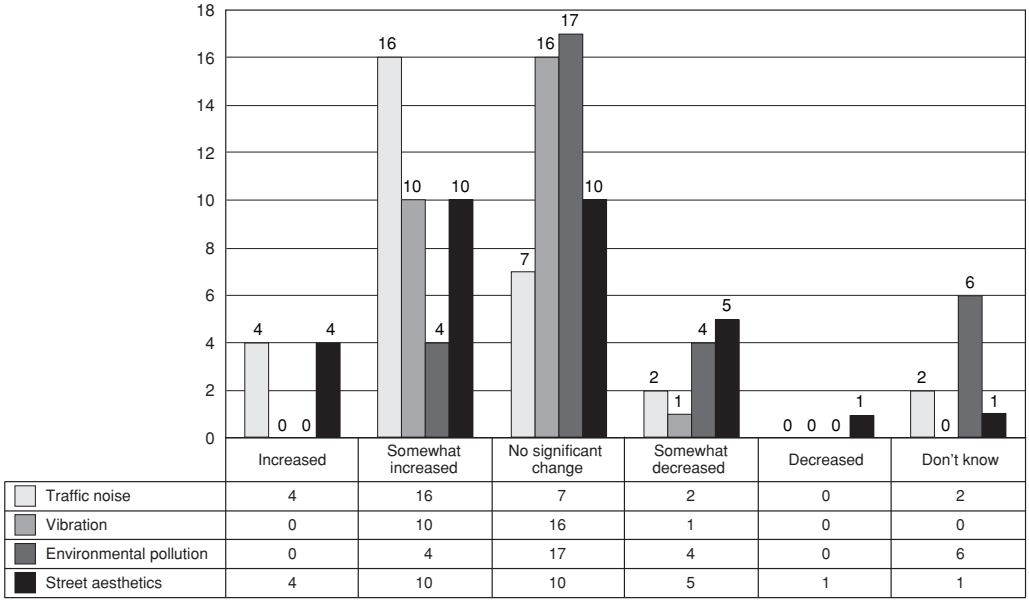

Fig. 8 Existing situations explaining the effect of traffic calming device/s

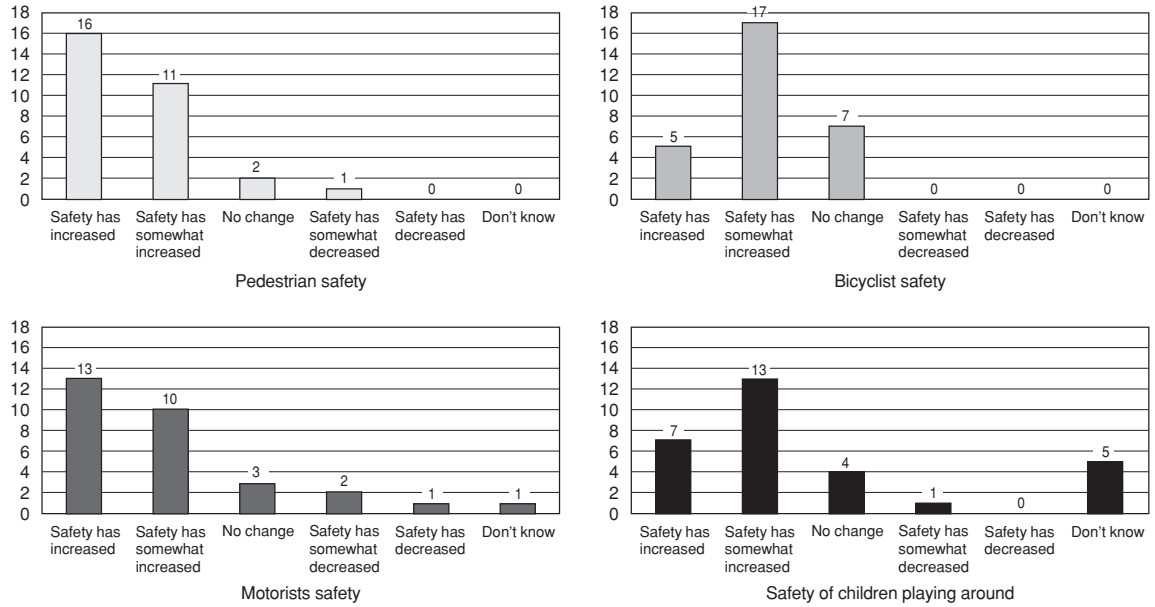

Fig. 9 Safety situations after traffic calming device installation

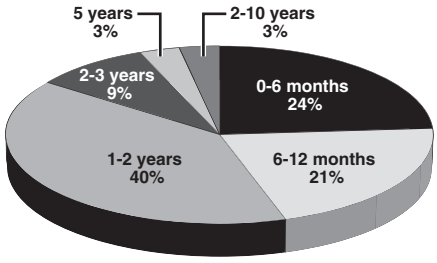

Fig. 10 Period for completion of one project

cess to proceed.

There may be several instances for which the transportation agencies need to remove traffic calming devices. The survey reveals that 49% of the respondent agencies had to remove traffic calming devices due to several reasons, while 51% of the cities never removed devices once they installed them. Table 8 illustrates the instances for which the transportation agencies had to remove or relocate the devices.

Table 8 Reasons for removal of traffic calming devices

Country	Province (State)	Reasons for removing the traffic calming device
USA	Albuquerque (NM)	Political pressure
USA	Greenville County (TX)	Hump caused drainage problems
USA	Portland (OR)	i) no longer needed and removed ii) project modified to achieve results without negative effects
USA	District of Columbia (WA)	Illegal installation or multiple violation
USA	Bellevue (WA)	i) Council requested installation going against recommendations of staff. ii) Did not work and residents requested removal.
USA	Northport (AL)	Changed location of device
USA	Peoria (AZ)	Emergency vehicle
Canada	Calgary (AB)	Transit requirements (i.e. bus could not make turn with device in place)

5. DISCUSSION

Several cities have implemented traffic calming measures to reduce vehicle speed and volume. Cities require documentation of a minimum threshold level of public support prior to construction of the traffic calming device. The neighborhood support determines the amount of residents support for the proposed traffic calming. The method for determining neighborhood support may vary for different jurisdictions. This research revealed the transportation agencies' minimum requirement of neighborhood support to install a traffic calming device. The average level of desired neighborhood support was 67%. The minimum level of neighborhood support varied. The City of Sandy, Oregon requires 50% public support, while Dublin, Ohio requires 95% support from those residents who either live on or are directly adjacent to the street in question. The result shows that minimum threshold level of public support prior to construction varies from 61% to 70% for 41% of the respondent agencies.

The survey revealed that residents support for traffic calming before device installation varies from 10% to 100%. Whereas residents support for traffic calming after device installation varies from 0% to 95%. The average level of neighborhood approval before traffic calming device installation is 74% and after device installation is 67%.

The survey explores the level of neighborhood opposition and/or controversy for which the cities cannot install traffic calming device. The average level of neighborhood opposition and/or controversy is 67%. This research explored that neighborhood opposition and/or controversy varied from 1% to 80%. The City of Bellevue, Washington cannot install if 1% of residents say they do not want the device. Lakeland, Florida cannot install a device for 79% opposition from the residents.

This research explored that speeding is the most significant issue for traffic calming. The issues of next greatest importance were pedestrians' safety concerns, high volume of traffic, crashes, lack of sidewalks and lack of pedestrian crossing. High volume of traffic and pedestrian safety concerns were "significant issues" for traffic calming. Lack of pedestrian crossings and lack of sidewalks were "somewhat significant" factors and crashes were "insignificant" factor for the issues for traffic calming.

This research found common practices of device selection depending on the nature of issues. The research explores that speed humps were suitable for various types of street issues such as speeding, high volume of cut through traffic, crashes, pedestrians safety concerns, pedestrians safety issues due to lack of sidewalks and for narrow streets. Community support was the most important factor during the selection of a traffic calming device. Traffic volume, traffic speed and cost effectiveness were the next important factors of consideration during the selection of a traffic calming device.

The findings summarize the list of employed devices by the respondent agencies. Most cities are required to perform a follow-up evaluation of the effectiveness of the traffic calming feature, and to specify a time range in which the evaluation should be accomplished after installation. Cities often require that the feature be installed for long enough that any evaluation data is not biased by the newness of the feature. During the evaluation, the city determines the traffic speed, volume or other measures and compares the data for assessment. This survey revealed the effectiveness of traffic calming devises. The results show that traffic calming had "decreased" the traffic speed, "somewhat decreased" the traffic volume, "no significant change" in accident, "somewhat increased" the residents'

satisfaction and agreement. This research explored the respondents' opinion regarding the existing situations which explain the impact of traffic calming device/s to the nearby dwellings. From the results it was found that due to traffic calming, traffic noise had "somewhat increased", vibration and environmental pollution had "no significant change", and street aesthetics had "somewhat increased" or there was "no significant change".

This research revealed the factors of consideration during the selection of a traffic calming device. From the result it was found that community support was the most important factor for the selection of a traffic calming device. This survey explored the effectiveness of traffic calming devices. The results show that traffic calming had "increased" pedestrians' and motorists' safety, "somewhat increased" the bicyclists' safety, and "somewhat increased" the safety of children playing in the vicinity The results showed the available safety situations which are appropriate with the circumstances after the traffic calming device had been implemented. The survey explored the transportation agencies' period for completion of a project. Most (40%) of the responding agencies required 1 to 2 years for completion of a project.

A single resident can request a traffic calming needs assessment. In some cities a minimum neighborhood support is needed to evaluate the need for traffic calming. Usually the surveyed agencies define what level of community support is necessary for the traffic calming programs. In most cases the surveyed jurisdictions have a specific process for selecting traffic calming projects, which may involve developing a traffic calming plan in consultation with area residents, or simply a petition signed by a certain percentage of residents on a street for consideration of traffic calming.

The property owners or residents of an area in which traffic calming has been implemented may request the removal of the traffic calming devices. A request to remove the traffic calming features may be considered by the city subject to several conditions, for example request for the removal of the traffic calming features must be signed by a certain percentage of affected residents or property owners within the same neighborhood and a majority vote from the affected property owners is required for the removal. For removal of the device, Cities require some degree of public support which is higher than that necessary to install traffic calming. The surveyed jurisdictions removed traffic calming devices under several conditions and some of the cities described the conditions. It is generally believed that a higher level of residents approval before construction of traffic calming features will lead to fewer requests for removal.

6. CONCLUSIONS

It is an important issue to determine the level of public support needed to remove traffic calming features. Cities determine the level of community support for the traffic calming program and discuss the program with residents and/or property owners to identify street issues and to determine objectives for the neighborhood. The transportation agencies install temporary traffic calming devices and measure the residents support for the devices to be permanent.

Community participation is an important component for all traffic calming projects. Practices have shown that traffic calming projects that are implemented without involving the residents are commonly unsuccessful, resulting in the removal of the device. Hence the city's goal is to let the residents become actively involved in the traffic calming design and decision-making process.

North American traffic calming progrms ensure notably close contact with residents. Although these programs are very much sophisticated; it has several limitations. Implementation of their traffic calming process is greatly influenced or interrupted by political pressures. Several Asian cities have implemented traffic calming measures such as speed humps, speed tables, traffic circles, curb extensions, diverters, medians and a range of other measures to slowdown or to discourage excessive traffic. Although few cities have been successful with such efforts, some have created more problems than they have solved. Such a situation is noticed in many Asian countries like Japan and Korea due to the lack of effective traffic calming process. Several traffic calming devices have been installed in Japan. But these are not very effective and popular since no standard design guideline was followed during the process. Residents do not have much knowledge about traffic calming in Japan which leads to the unpopularity of traffic calming. Traffic calming programs, for example Kurashino Michi Zones, are not very well accepted by Japanese people. The number of Kurashino Michi Zone is also not so high. Typically such a situation occurs when traffic calming measures are applied without an overall plan. Hence Asian communities should develop a systematic traffic calming device selection process in order to make the traffic calming program successful. This research demonstrates that well designed traffic calming programs can be considerably advantageous. Successful programs are usually well supported by the public.

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